GLAST LAT
Calorimeter Subsystem
Dual PIN Photodiode Procurement
Readiness Review

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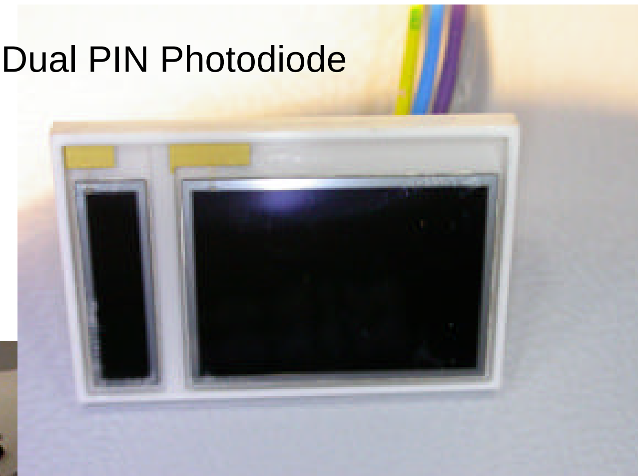
Outline

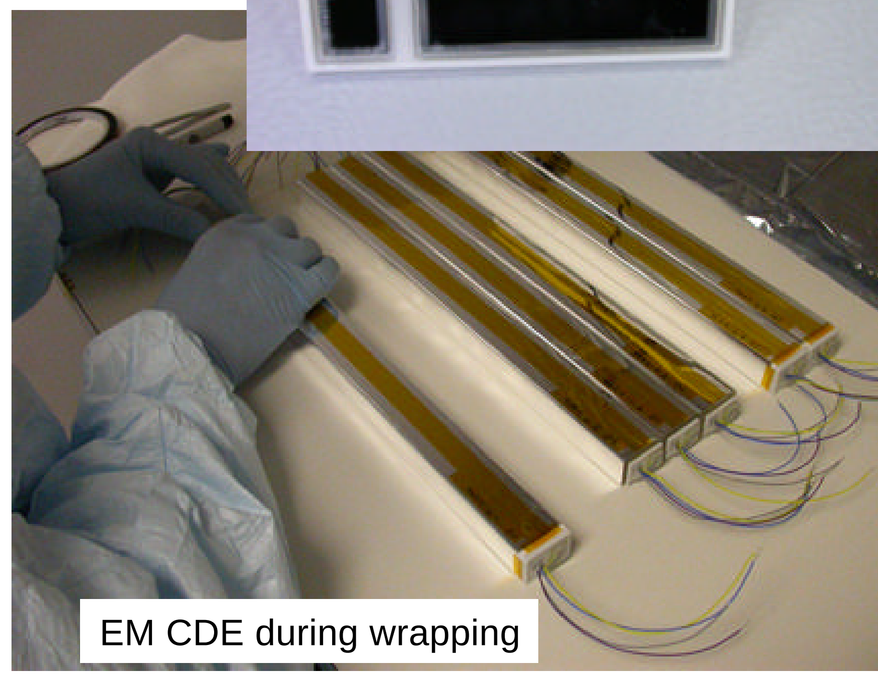
- Introduction
- Responsibilities
- Requirements
- M&P Status
- EEE Parts Status
- Verification and Testing
- Procurement Costs, Schedule and Issues
- Risks

CAL Crystal Detector Element

- **CAL consists of 16 Modules**
  - Each Module has 96 CsI Crystal Detector Elements (CDE)
  - Each CDE has two Dual PIN Photodiodes (DPD), one DPD on each end.
  - Total of 3072 diodes in flight
- **Requirements on the DPD are integrally linked to the performance of the CDE and ultimately CAL.**
  - Collects the light from energy depositions in the CsI (SIGNAL)
  - DPD electrical characteristics (capacitance and dark current) affect the front end electronics NOISE.
  - Desire is to maximize SIGNAL/NOISE.

CAL EM Dual PIN Photodiode





EM CDE during wrapping

CAL PIN Photodiode History

- **7 years of CAL concept development – Crystal Detector Element**
  - CsI(Tl) crystals readout w/ PIN photodiodes at each end
  - Hodoscopic arrangement of crystals gives 3D positions
  - 4 prototype calorimeters, 7 Beam Tests
  - Close working relationship w/ Hamamatsu in developing design

NASA ATD Program

Commercial PIN

PIN Diode	Dates	Optical Window Material	Silicon Die thickness (um)	PIN A Area (mm^2)	PIN B Area (mm^2)
S3590	1/1996 – 12/1998	Hard epoxy resin		n/a	100
S3590-08 SPL	2/1999 – 10/2001	Hard epoxy resin	200	24	96
S8576	1/2001 -	Hard epoxy resin	300	25	152
S8576-01	2/2003 -	Silicone resin	300	25	147

EM DPD

Flight DPD

Responsibilities

- **Development of the CAL Dual PIN Photodiode requirements and specifications has been a joint responsibility of the Naval Research Lab and CEA/DAPNIA in Saclay.**
  - Worked closely with Hamamatsu in USA and Japan.
  - Lead for design and testing issues at NRL is J. Eric Grove.
  - Lead for design and testing at CEA is Philippe Bourgeois.
  - Nick Virmani at NRL has lead responsibility for EEE Parts, manufacturability and quality assurance issues.
  - DPD Procurement, qualification and screening document has been constantly updated in joint collaboration w/ CEA and Hamamatsu. Rev 11 is final and approved by CEA, NRL and HPK. Meeting in Japan on Feb 20th will resolve any outstanding TBDs.
- **The flight procurement is a joint responsibility of NRL and CEA.**
  - CEA contributions
    - qualification and acceptance screening of all DPD
    - procurement of ~200K $US in flight diodes.
  - NRL contributions
    - overall management of the effort,
    - coordination and negotiation of the specification, and
    - procurement of the residual flight diodes (~$400K).

DPD Requirements

- **CAL Flight Dual PIN Photodiode Specification, LAT-DS-00209-11**
  - **Electrical and Optical Requirements**
    - **Area, sensitivity, dark current, capacitance, bias voltage**
  - **Ceramic Carrier Requirements – mechanical**
    - **Dimensions and tolerance control, electrical leads**
  - **Manufacturing Requirements and process control**
    - **Die attach, wire bonds, optical window encapsulant**
  - **Product Assurance Requirements – Qualification and screening**
    - **Constant in process control, monitors and feedback**
  - **Environmental Requirements**
  - **Deliverables – Documentation and data package**
  - **Shipping and handling**
  - **Acceptance Criteria**
- **Crystal Detector Element Specification, LAT-SS-01133-02**
  - **DPD bonding to CsI**
  - **Electrical lead treatment and positioning.**

Qualification Status

- **Materials and Processes Status**
  - ShinEtsu KJR 9022E silicone resin has been approved by GSFC with the condition of 24 hour bakeout at 175 degC. This is part of the DPD manufacturing plan at Hamamatsu
- **EEE Parts Status**
  - Preliminary testing on EM DPD has been performed to gain confidence in flight part testing.
  - Qualification testing will be performed on flight DPD lot. Prototype flight parts arriving this month will be tested in France.
  - Expect no problems based on current knowledge and testing.
  - DPD specification has been reviewed by Parts Control Board and we have been advised to go ahead with the plan.

Changes from EM to Flight DPD

- Ceramic carrier size – S8576-01 carrier is 1 mm smaller in width and length.
- PIN B silicon die active area – S8576-01 die is 0.5 mm smaller in one dimension (~3%).
- Electrical lead positions have been moved.
- Electrical leads shall be tinned by Hamamatsu prior to assembly of the silicon die to the carrier.
- Optical window encapsulant is changed to Shin Etsu silicone resin.
- Shipping container has been modified to provide ESD protection and to protect the electrical leads from bending.

EM Verification and Testing

- **An extensive test program studied the dual EM DPD (LAT-DS-00072-03).**
  - ~ 650 parts (S8576) were purchased. These were used in part evaluation, bonding studies, and assembly of CDEs for the Engineering Model CAL module.
  - Performance data is mostly in the form of assembled CDE performance.
  - Part evaluations were performed in France by CEA and Serma Technologies and evaluation feedback incorporated in the latest Rev 11 flight DPD spec.
- **CDE Performance Results – Exceeds Requirements**
  - For the EM, 124 CDEs were manufactured – 110 at NRL and 14 at CEA/DAPNIA. Of these, 124 CDE, 113 were accepted as available for EM assembly. The rejections are attributable to a failure in the bonding procedure and have nothing to do with the diode.
  - The light yield for the EM CDEs was found to be 8500 e/MeV. This is compared with the CAL Level IV spec of >5000 e/MeV. This significantly greater than spec'ed yield is caused by the larger area of the low energy PIN diode and the improved light yield associated with the VM2000 wrapping on the CDE.

Verification and Testing (cont)

- **Part Evaluation – Problems w/ epoxy window, electrical leads**
  - Hard epoxy window of S8576 could not withstand the thermal cycling at qualification temperature range (-30,+50 degC, 100 cycles). This necessitated the change to ShinEtsu Silicone resin for the Flight DPD and testing performed at NRL has shown no problems.
  - Cracks, bends, scratches on electrical leads apparently caused by errors in handling, storage in foam, and optical surface polishing tooling. Flight DPD spec prohibits storage in foam, requires no polishing, and has improved ESD shipping container.
  - Electrical leads will be tinned by manufacturer on flight diodes – no corrosion problems.
- **Bonding to CsI – Find strengths over x5 required strengths.**
  - 90 sample bonds of BTEM and EM DPD to CsI crystals have been made. These samples were thermal cycled over the qualification range (-30, +50 degC). Some samples received over 100 thermal cycles. Light yield performance of the units was tested at 6 – 8 cycle intervals. After an initial drop of ~5% in yield thought to be caused by wetting of the Tetratek optical wrap to the crystal, no significant change in light yield were observed.
  - Bond strengths were tested on samples before and after thermal cycling. Typical shear strengths were 400 N (requirement is 35 N) and typical pull strength was 250 N (requirement is 10 N).

Flight DPD Verification & Testing

- **Essentially all EM DPD testing is relevant to the Flight DPD with the exception of the new ShinEtsu Silicone optical window and any potential impact on performance or bonding to CsI.**
  - A complete evaluation of the flight DPD will be performed on the prototype units available this month.
  - Testing to date on these issues was limited by parts with ShinEtsu silicone optical window and was limited to commercial diodes (S5107) using the ShinEtsu silicone window and 10 EM DPD assemblies that were filled with the ShinEtsu silicone rather than the hard epoxy.
- **The testing of these issues is summarized the the LAT-TD-1476-01 report – no significant problems detected.**
  - We find bond strengths essentially unchanged.
  - No problems in qualification thermal cycling at 100 cycles. Some tests to 180 cycles.
  - We find light yields of about 90% of those of the EM CDE but attribute the difference to poor quality bonds at the far end of the xtal. We expect no change in light yield.

Procurement Quantities

Level	Operation or Loss Process	Loss %	Loss Count	TOTAL CNT
CDE	**Required CDE for Flight**			**1728**
	Flight Spares	6.4%	110	1838
	CEA Delivery to NRL			**1838**
	Acceptance Test Failures	1.0%	19	1857
DPD	**DPD for CDE Acceptance Test**			**3714**
	Bonding Process Fallout	10.0%	413	4127
	PhotoDiode Assy Fallout	2.0%	84	4211
	Solder/Stake Failures	1.0%	43	4254
	Spare DPD	2.0%	87	4341
	Electrical Screening Fallout	1.0%	44	4385
	Dimensional Fallout	1.0%	44	4429
	Lot Acceptance Test	1.0%	45	4474
	DPD Qualification		60	4534
	DPD Evaluation		48	4582
	Bonding Process Development		100	4682
	TOTAL DPD Requirement			**4682**

Deliveries in quantities of 600 DPD

Schedule

- **First flight deliveries needed June, 2003. Hamamatsu requires 3.5 months to manufacture.**
- **Order of additional parts will require ~ 4 months to deliver so get the number correct the first time.**
- **First two months of manufacturing are for fabrication of the ceramic carriers. Assembly and test of the DPD are the remaining time.**
- **Deliveries are based on 600 diodes at 5 week intervals for the 1st 4 deliveries and 3 week intervals for the remaining 4 deliveries.**

Risk Assessment

- **Bonding to CsI**
  - Testing to date show no significant difference in bonding of the ShinEtsu-filled EM DPD to CsI. Bond strengths on the limited number of samples available indicate strengths that exceed requirements by large factors. The tests show that the ShinEtsu is well attached to the ceramic carrier – the ultimate failure of the bond is at the surface of the DC93-500 to the diode or the crystal, not interior to the diode window material.
  - NRL used its CDE bonding tooling to bond 6 of the ShinEtsu-filled EM DPDs to CsI and found no particular additional difficulty in executing the procedure relative to the standard EM DPD. This issue needs to be verified with the CEA tooling and with its industrial partner. The major issue relative to the bonding tooling is the concavity of the ShinEtsu-filled diode window relative to the flat, hard surface of the EM DPD. This concavity has to be considered in light of leakage of bonding material in the tooling. This was not a problem with NRL tooling; it must be verified by CEA.

Risk Assessment (2)

- **Radiation Susceptibility**
  - The only outstanding radiation susceptibility of the Flight DPD is related to the change to the ShinEtsu silicone optical window. All other elements of the diode have been investigated in the EM DPD testing. We need to verify the radiation hardness of the ShinEtsu and any impact on optical sensitivity of the DPD. This testing is planned with the prototype DPD that are available in late February. Additionally, a quick comparison with respect to the EM DPD will be performed next week by radiating a CsI cube with two DPD attached – an EM DPD and a ShinEtsu-filled EM DPD. This should identify any significant problem with radiation exposure.

Risk Assessment (3)

- **Qualification**
  - As part of the first delivery of the Flight DPD lot, CEA will conduct qualification and lot acceptance tests. In the best of all worlds, manufacturing and delivery of additional DPD would be suspended until the qualification testing was completed. This is not possible with the current CDE production schedule. The early delivery schedule is a shipment of 600 DPD every 5 weeks. Consequently, the LAT team may be liable for all units in production until the completion of the qualification testing is complete.
  - We mitigate this liability by early evaluation of the prototype flight DPD produced with flight processes and controls that will be available in February. These tests are expected to provide the confidence that there will be no issues with the flight lot qualification.

Risk Summary

- **Risk Removal**
  - Most of the residual risk in proceeding with the DPD procurement could be removed by delaying the flight DPD procurement and, by result, the delivery of the flight CAL modules by about one month or until the evaluation of the prototype flight DPD is completed.
  - The residual risk relative to bonding of the DPD to CsI will not be removed until CEA and its industrial partner develop the tooling and execute test bonds with the prototype flight DPD. It appears that this testing is not possible until May 2003 at the earliest.
  - The completion of the testing of the EM CAL module is not believed to be a significant step in risk removal.
- **Summary**
  - The risks are minor and are not likely to impact the reliability of the DPDs. Lets press on.